

Status of the Endangered Scotts Valley Spineflower (Polygonaceae) in Coastal Central California

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Abstract.—*Chorizanthe robusta* var. *hartwegii* (Scotts Valley spineflower, Polygonaceae) is a narrow endemic plant restricted to a specialized microhabitat (exposed bedrock in California prairie) in Santa Cruz County, California. This taxon and the nominate variety were listed as endangered under the U.S. Endangered Species Act in 1994. Three occurrences of *C. robusta hartwegii* exist on four properties in a recently urbanized area at the northern edge of the city of Scotts Valley. Ten of 80 known colonies are now likely extirpated. In 2014 the primary threats are habitat alteration due to adjacent land uses and developments, and invasive plant species (non-natives) and accumulation of thatch. Using international standards, *C. robusta hartwegii* is critically endangered: area of occupancy, 0.39 ha; extent of occurrence, 1.3 km²; landscape, severely fragmented; and quality of the habitat, continuing to decline. With these attributes, *C. robusta hartwegii* faces an extremely high risk of extinction. As a matter of urgency, we recommend reducing and controlling invasive plant species and thatch using a combination of methods: mowing with biomass removal, cutting by hand tools with biomass removal, pulling by hand with biomass removal, controlled grazing, prescribed mini-burns (testing 1 m²), and spot-treating invasive grasses with a grass-specific herbicide.

Chorizanthe robusta (robust spineflower) is a small annual plant (10 to 30 cm tall) in the buckwheat family (Polygonaceae) and endemic to coastal central California. Two varieties are recognized (Reveal and Morgan 1989, Baldwin et al. 2012): *C. robusta* var. *robusta* (robust spineflower), and *C. robusta* var. *hartwegii* (Scotts Valley spineflower). *C. robusta hartwegii* is diagnosed from the nominate variety by its consistently erect habit (not spreading) and rose-pink involucre lobes (modified leaves subtending the flower) rather than white. The species, inclusive of both varieties, was listed as endangered under the U.S. Endangered Species Act in 1994 (U.S. Fish and Wildlife Service [USFWS] 1994).

The systematics of the species comprising *Chorizanthe* are difficult, confusing (Reveal and Hardham 1989) and unresolved (Kempton 2012). In particular, using molecular techniques and frequencies of haplotypes, Brinegar and Baron (2009) considered *C. r. robusta* to be more closely related to *C. pungens* var. *pungens* (Monterey spineflower) and *C. robusta hartwegii* to be more closely related to *C. pungens* var. *hartwegiana* (Ben Lomond spineflower). Because of their restricted habitats, small geographic ranges and identified threats, *C. p. pungens* and *C. pungens hartwegiana* were likewise listed under the U.S. Endangered Species Act in 1994 as threatened and endangered, respectively (USFWS 1994). Brinegar and Baron (2009) suggested that the four taxa could be

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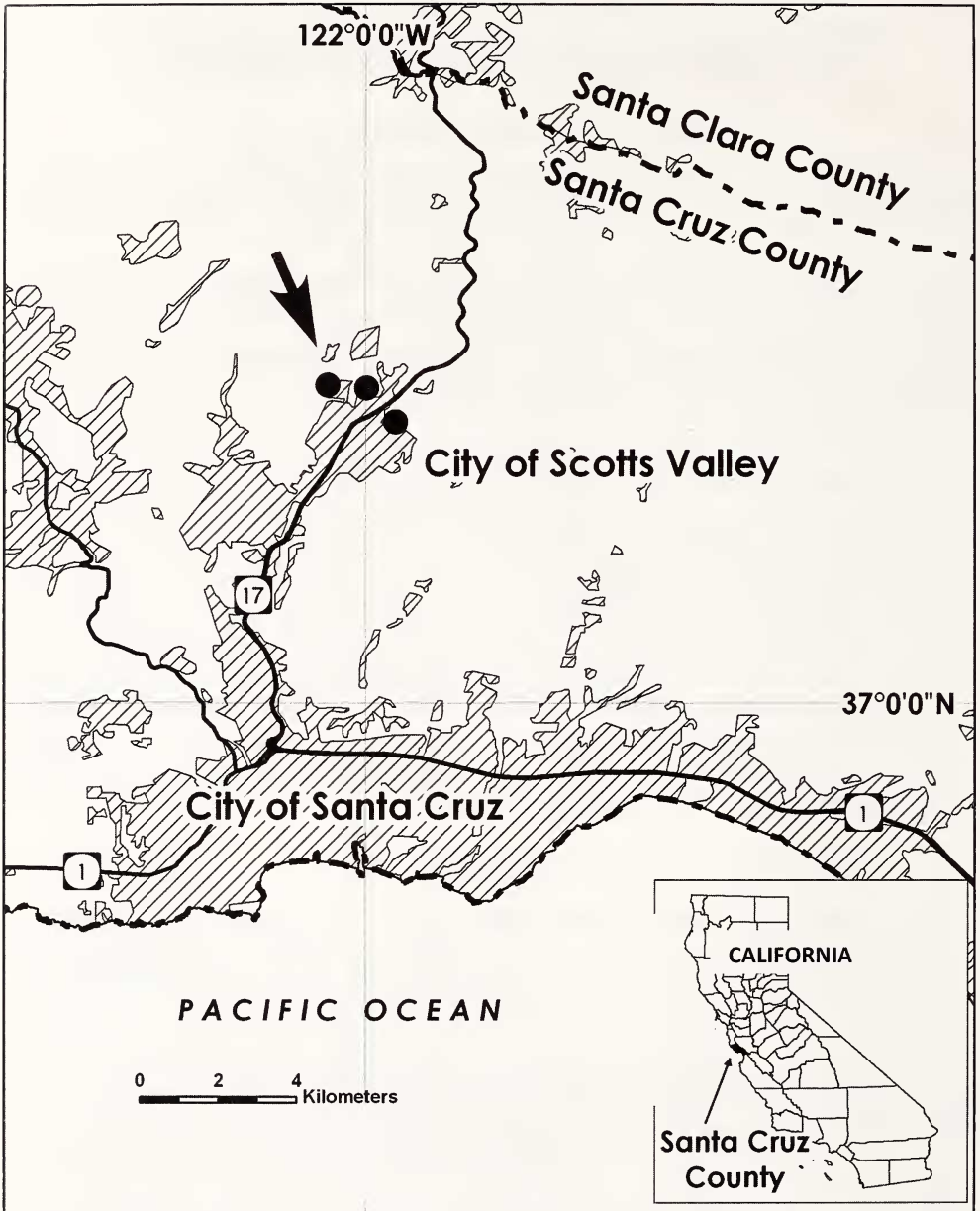


Fig. 1. *Chorizanthe robusta* var. *hartwegii* (Scotts Valley spineflower, Polygonaceae) at the northern edge of the city of Scotts Valley, Santa Cruz County, California. The three occurrences are on four properties. Hatching indicates developed areas.

recognized as four varieties of *C. pungens*. However, Baldwin et al. (2012) continued to recognize *C. r. robusta* and *C. robusta hartwegii* as comprising a separate species.

Reveal and Morgan (1989) reported that *C. robusta hartwegii* exists as three occurrences in the vicinity of the city of Scotts Valley, Santa Cruz County, and 11 km inland from the Pacific Ocean (Figure 1), all within 1.5 km of each other: a western occurrence with several thousand plants, a central occurrence with < 1,000 plants, and an

eastern occurrence with $\approx 1,000$ plants. At Federal listing in 1994 the taxon was still known from only three occurrences on four properties. Based largely upon our survey and census data for 1992, USFWS (1994) reported that numbers for the central occurrence and part of the western occurrence ranged from 30,000 to 100,000 plants. Identified threats were a proposed residential development and golf course on three properties with the central and western occurrences, a proposed commercial development on the property with the eastern occurrence, inadequate legal protection and stochastic events.

USFWS (1998) issued a recovery plan for *C. robusta hartwegii*. It recommended preventing extinction by establishing conservation easements, restricting activities to those compatible with the plant, and/or a conservation organization acquiring the four properties. However, USFWS (1998) recognized that recovery might not be possible due to the small geographic range and limited conservation opportunities. New threats included urban development projects (residential developments that would affect all three occurrences, and roads and water facilities near the western occurrence), trampling, invasive plant species (non-natives), pesticides, fertilizers and altered hydrologies. USFWS (2002) reported the total occupied area comprised < 0.4 ha (our data) and considered the following habitat components essential to conservation of *C. robusta hartwegii*: the thin soils in the Bonnydoon series over outcrops of Santa Cruz mudstone and Purisima sandstone, the wildflower fields on the thin soils, the plant community of the California prairie along with the pollinators and seed dispersal mechanisms, the areas around each occurrence for re-colonizing suitable habitat, and the landscape in the watershed above the habitat for maintaining edaphic conditions and hydrology. USFWS (2009) reviewed the status of the taxon and recommended no change in its listing status. Our purpose is to review and enhance the knowledge of *C. robusta hartwegii*, in particular its distribution, ecology, abundance, threats, management and conservation status in 2014.

Methods

The only primary publications regarding *C. robusta hartwegii* are Reveal and Morgan (1989), USFWS (1994, 1998), and Brinegar and Baron (2009). We have additional and unpublished data because we surveyed, mapped and measured the colonies (spatial groups of separate individuals), censused and made observations during many years from 1990 to 2014. Our surveys and censuses were conducted by systematic search and count when the plants were flowering (April to July). We counted and estimated (after gaining experience by counting) numbers of plants in the following manner: in a colony with < 200 individuals, each plant was counted; in a colony with 200 to 1,000 individuals, plants were estimated to the nearest 20-individuals; and in a colony with > 1000 individuals, plants were estimated to the nearest 100-individuals. We measured cover (relative percent) by native and invasive plant species (in 0.1-m quadrats at 1-m intervals) in May and June 2012 along eight transects (95 m total length) through eight colonies on Polo Ranch Open Space Preserve ($37^{\circ}3.88'N$, $121^{\circ}59.60'W$) and along three transects (29 m total length) through three colonies on the western part of Glenwood Open Space Preserve ($37^{\circ}4.32'N$, $121^{\circ}59.00'W$). The transects extended 4.6 m beyond each side of the occupied rock outcrops. Using all available information, we summarize and enhance the knowledge of *C. robusta hartwegii*, including its distribution, ecology, abundance, threats, management and conservation status in 2014. We consider a location with the species as a separate occurrence if it is > 0.4 km from the nearest occurrence (California Department



Fig. 2. The three occurrences of *Chorizanthe robusta* var. *hartwegii* (Scotts Valley spineflower, Polygonaceae) at the northern edge of the city of Scotts Valley, Santa Cruz County, California. The polygon with W encompasses the western occurrence on Salvation Army land, Scotts Valley High School land, and the western part of Glenwood Open Space Preserve. The polygon with C encompasses the central occurrence on the eastern part of Glenwood Open Space Preserve. The polygon with E encompasses the eastern occurrence on Polo Ranch. The Google Earth image is dated 14 April 2013.

of Fish and Game 2011). Latin and common names of plants follow Baldwin et al. (2012). The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the USFWS.

Review of *Chorizanthe robusta* var. *hartwegii*

C. robusta var. *hartwegii* is a narrow endemic plant restricted to the specialized microhabitat of exposed bedrock in California prairie (as defined by Holstein 2011, equates to California annual grassland of Sawyer et al. 2009) in coastal central California. In 2014 the taxon is still known from only three occurrences on four properties in a recently urbanized area at the northern edge of the city of Scotts Valley (Figure 2). The western occurrence is on three contiguous properties: Salvation Army land (37°4.30'N, 122°0.58'W; private), Scotts Valley High School land (37°4.16'N, 122°0.53'W; public), and the western part of Glenwood Open Space Preserve (public). The central occurrence is on the eastern part of Glenwood Open Space Preserve. These two occurrences are west of State Highway 17, which is an expressway through the city. The eastern occurrence is

on Polo Ranch Open Space Preserve (private) and east of State Highway 17. Scotts Valley High School land, Glenwood Open Space Preserve and Polo Ranch Open Space Preserve are within city limits, whereas Salvation Army land is not. The geographic range comprises 1.3 km², with 1.2 km separating the western and eastern occurrences. We have identified 80 colonies since 1990: western occurrence, 38 colonies; central occurrence, 8 colonies; and eastern occurrence, 34 colonies.

The landscape in which *C. robusta hartwegii* occurs is inhabited also by three other endangered species: *Polygonum hickmanii* (Scotts Valley polygonum, USFWS 2003), *Plagiobothrys diffusus* (San Francisco popcorn flower, California Department of Fish and Wildlife 2013), and *Cicindela ohlone* (Ohlone tiger beetle, USFWS 2001). We and others have conducted numerous searches for all four taxa. Although *C. robusta hartwegii* is a small plant, its microhabitat is easy to identify. Some additional occurrences may exist but have not been found. However, most other areas likely to have supported this taxon are now developed, and it seems unlikely that any additional occurrences exist. Development of the city of Scotts Valley and construction of State Highway 17 probably removed any other occupied habitat. *P. hickmanii* is endemic to and occurs on three of the properties (Kofron et al. 2013). *P. diffusus* occurs on two of the properties (pers. obs.) and *C. ohlone* on one (Cornelisse et al. 2013, Knisley and Arnold 2013), although each has a broader geographic range.

C. robusta hartwegii germinate during the winter (wet season), flower during April to July, dry and turn a rusty hue during the summer (dry season), and eventually break apart during the fall. Depending on vigor of individual plants, dozens to possibly hundreds of seeds are produced per plant, with seed maturation by August. The plants occur in colonies in full sun in California prairie at 229 to 244 m elevation (Reveal and Morgan 1989) in two types of situations: in patches of thin soil overlying and derived from exposed bedrock (Santa Cruz mudstone and Purisima sandstone) on gently sloping to nearly level ground, and on steep outcrops of the exposed bedrock. In the vicinity of the city of Scotts Valley, California prairie is generally on the middle to lower slopes (213 to 244 m, Hinds and Morgan 1995), with *Sequoia sempervirens* (redwood) and mixed forest on higher slopes (USFWS 2003). Based on data for the Ben Lomond weather station (6.3 km west northwest of Salvation Army land), mean annual rainfall at the three occurrences is \approx 1,186 mm, along with rain primarily from November to April (<http://www.worldclimate.com> 2013). Other important factors appear to be the particular characteristics of the thin soil: its fine texture, relative sterility and distinctive hydrology (Kofron et al. 2013). In addition, many of the patches of thin soil bear a cryptogamic crust (cyanobacteria, lichens, mosses and fungi on the soil surface). Cryptogamic crusts are important elements of semiarid and arid ecosystems (Beymer and Klopatek 1992) because they stabilize soil against erosion, fix atmospheric nitrogen, form organic matter (Eldridge and Greene 1994), retain soil moisture, discourage weed growth (Belnap et al. 2001) and provide favorable sites for growth of native plants (e.g., Lesica and Shelly 1992). We have observed *C. robusta hartwegii* growing both in and beyond the cryptogamic crusts.

In 2014 the local California prairie is dominated by invasive annual grasses (Poaceae) that include *Aira caryophylla* (silver hair grass), *Avena barbata* (wild oat), *Briza maxima* (rattlesnake grass), *Bromus hordeaceus* (soft chess) and *Festuca myuros* (rattail sixweeks grass), which produce thatch. However, some patches of thin soil associated with the exposed bedrock are still dominated by native annual forbs that comprise a distinct community of native wildflowers, which USFWS (1994, following Holland 1986) referred

to as wildflower fields. The native species associated with *C. robusta hartwegii* in this plant community include the equally narrow endemic *P. hickmanii*, *Acmispon brachycarpus* (deervetch), *Castilleja densiflora* (owl's-clover), *Deinandra corymbosa* (coastal tarplant), *Lasthenia gracilis* (common goldfields), *Lepidium nitidum* (peppercress), *Minuartia californica* (California sandwort) and *Trichostema lanceolatum* (vinegar plant). The greatest diversity of native plants within the wildflower fields is generally on the thinner soil. The soil underlying most other parts of the local California prairie is thicker and with more humus and nitrogen.

The proposed residential development and golf course that threatened the central and western occurrences in 1994 were never built. However, other developments have directly or indirectly impacted them: the Scotts Valley Water District recycled water tank, the Scotts Valley High School, and the residential developments immediately east and west of the central occurrence. The commercial development that previously threatened the eastern occurrence was completed in 1994 (Borland International Headquarters) and without direct impacts.

Salvation Army Land (Part of Western Occurrence)

Salvation Army land comprises 83 ha of California prairie and forest immediately west of Scotts Valley High School land and Glenwood Open Space Preserve. We have recorded 13 colonies on the property (all on the southern half), one of which is shared with Glenwood Open Space Preserve (west). In the mid 1990's, the California Department of Fish and Game recommended that one large preserve be established for the sensitive plant species on Salvation Army land and the adjacent part of Scotts Valley High School land. However, negotiations for a conservation easement on Salvation Army land were not successful (California Department of Fish and Game 2004). Scotts Valley Water District built a recycled water tank on this property in 1999 (USFWS 2003), along with a paved road 20 m upslope of five colonies. We conducted two surveys and censuses on this property (Table 1): 1992 (32,066 plants), and 2009 (6,336 plants). The natural ecosystem on Salvation Army land is now impacted by development and also degraded by invasive plant species and accumulation of thatch. Intensive management is urgently needed.

Scotts Valley High School Land (Part of Western Occurrence)

Scotts Valley High School land (8 ha) is bounded by Salvation Army land to the west and Glenwood Drive and residential development (mostly Glenwood Estates, 45 houses on 14 ha) to the east. Construction of the high school commenced in 1998. Four colonies of *C. robusta hartwegii* (790 plants in 1998) were in the construction footprint of the high school, which we salvaged in 1999 and transplanted (soil with seed bank) to a revegetation area on the western part of the property that is subject to a management plan in perpetuity. However, this area was subsequently compacted by heavy equipment, and no *C. robusta hartwegii* emerged. The Scotts Valley High School Ecological Preserve (3.2 ha of California prairie) was established on the southern part of the property to conserve some of the sensitive plant species (*C. robusta hartwegii*, *P. hickmanii*, *P. diffusus*), and it is subject to a management plan in perpetuity. We have identified 13 colonies in the ecological preserve. Development surrounds it on three sides: high school facilities, paved road and athletic fields immediately north; and houses immediately south and east. Although now fenced, students previously crossed the ecological preserve, bicycle jumps were erected in it, golfers used it for practice, and concrete and other waste

Table 1. Approximate numbers of *Chorizanthe robusta* var. *hartwegii* (Scotts Valley spineflower, Polygonaceae) at the northern edge of the city of Scotts Valley, Santa Cruz County, California, from 1992 to 2012. We surveyed and censused by systematic search and count when the plants were flowering (April to July).

Occurrence	Property	Year															
		1992	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2012
Western	Salvation Army land	32,066													6,336		
	Scotts Valley High School land	16,980	16,500	16,500	5,000	15,250	11,500	12,000	13,000						10,525		17,236
	Glenwood Open Space Preserve	41,141								25,237	28,118	10,642	11,201	9,451	16,769	29,899	
Central Eastern	Polo Ranch Open Space Preserve		7,950	6,322				13,595	9,931	7,799					19,246		14,150

were dumped in it (USFWS in Kofron et al. 2013). We saw no evidence of unauthorized activities from 2009 to 2013. Mowing without removing the cut biomass occurred annually from 1998 to 2011, and at our recommendation the cut biomass was removed in 2012. Also at our recommendation, controlled horse grazing to reduce the invasive grasses and benefit the sensitive plant species commenced in 2013.

We conducted nine surveys and censuses on Scotts Valley High School land from 1997 (16,980 plants in 17 colonies) to 2012 (17,236 plants in 13 colonies). In 1999 we recorded 5,000 *C. robusta hartwegii* on the property (all in the ecological preserve), which is the lowest number for any census. The low number likely resulted because of disturbances during construction of the high school, disturbances during construction of the road to access the water tank on Salvation Army land, and disturbances by construction and use of bicycle jumps in the largest colony. The natural ecosystem on the ecological preserve is now impacted by development and also degraded by invasive plant species and accumulation of thatch. The ecological preserve is not large enough to sustain a natural ecosystem, and the adjacent land uses on three sides are not compatible. The controlled horse grazing is expected to help improve the situation.

Glenwood Open Space Preserve (Central Occurrence and Part of Western Occurrence)

Glenwood Open Space Preserve comprises 67 ha of California prairie and forest that are north, northwest and east of Scotts Valley High School land (separated by Glenwood Drive and Glenwood Estates). In 1992 we documented 17 colonies (41,141 plants) on the property, one of which is shared with Salvation Army land. In 2003 the City of Scotts Valley and Ponderosa Homes agreed to development of Glenwood Estates, along with establishing the open space preserve with ownership by the City and an endowment for management (\$1,070,000). The houses were built from 2003 to 2005. Since 2003 the sensitive species and their habitats have been managed in accordance with a natural resource management plan. Controlled horse grazing commenced on the eastern part of the open space preserve (where eight colonies of *C. robusta hartwegii* have been recorded) in 2004, which appears to reduce invasive annual grasses and thatch. Since 2009 the City of Scotts Valley and the Land Trust of Santa Cruz County jointly manage the open space preserve. However, Scotts Valley Water District now has approval to install a facility on the property that could adversely affect *C. robusta hartwegii*. Although it is currently closed to the public, a plan to allow low-intensity recreation (e.g., hiking) is being prepared. In 2010 we observed only 10 colonies (29,899 plants): seven colonies were not seen, including five previously impacted by the dumping of construction debris and yard waste in the southeastern corner. In 2012 the invasive plant species on the western part of the open space preserve were primarily of families other than Poaceae: *Erodium botrys* (storksbill, Geraniaceae), *Hypochaeris glabra* (smooth cat's-ear, Asteraceae), *Linum* sp. (flax, Linaceae), *Logfia gallica* (daggerleaf cottonrose, Asteraceae), *Rumex acetosella* (sheep sorrel, Polygonaceae), *Silene gallica* (small-flower catchfly, Caryophyllaceae) and *Trifolium angustifolium* (narrow-leaved clover, Fabaceae). Cover by invasive plant species ($n = 11$) in the occupied habitat of *C. robusta hartwegii* was 79%, and cover by native plant species ($n = 3$) was 21%.

Polo Ranch (Eastern Occurrence)

Polo Ranch comprises 46 ha of California prairie and forest immediately north of residential development, and its natural ecosystem is now degraded by invasive plant species and accumulation of thatch. We conducted seven surveys and censuses of *C.*

robusta hartwegii on Polo Ranch from 1997 (7,950 plants) to 2012 (14,150 plants), and we have identified 34 colonies. In 2013 the occupied area (23 colonies) comprises 683 m². From 1998 to 2005 we observed disturbances to several colonies by grading for a firebreak and by off-highway vehicles, the latter which the landowner deterred by fencing in 2006. In 2009 the City of Scotts Valley approved a plan to construct 40 houses on 5 ha, along with establishing an open space preserve on 41 ha of which 12 ha of sensitive habitat would be fenced and under a conservation easement. The area under conservation easement will be managed by a conservation organization to benefit the listed plant species (*C. robusta hartwegii*, *P. hickmanii*, *P. diffusus*), including controlled grazing to reduce invasive plants along with other adaptive management practices. Although development will not destroy any occupied area, its footprint will extend to 30 m from the nearest colony of *C. robusta hartwegii* (USFWS 2012). Vegetation clearing for construction commenced shortly after our survey and census in June 2012. Cover by invasive plant species ($n = 22$) and native plant species ($n = 11$) in the occupied habitat was 94% and 6%, respectively, in 2012.

Conservation Status

The cessation of grazing (Salvation Army and Scotts Valley High School lands, 1970's; Glenwood Open Space Preserve, 1980; Polo Ranch, early 1990's) and fire suppression have likely contributed to the increasing presence of invasive plant species (and also rank natives such as *Baccharis pilularis* [coyote brush]) and accumulation of thatch. We suspect that grazing and fire previously benefited *C. robusta hartwegii* by reducing the invasive plant species and accumulated thatch in its habitat. The mechanisms by which the invasive species impact *C. robusta hartwegii* are not known, however, they may inhibit germination and seedling survival (e.g., Thomson 2005) or compete for limited resources. Also, it seems likely that accumulated thatch from the tall invasive annual grasses will eventually cover much of its microhabitat.

Species with small geographic ranges are more vulnerable to extinction by stochastic events (Ricklefs 2008), which include severe storms, freezes, harsh winters, fires and droughts (Mangel and Tier 1994). *C. robusta hartwegii* is a taxon with a small occupied area (0.39 ha, measured 1990 to 2002) and a small geographic range (1.3 km²). With these attributes, *C. robusta hartwegii* is highly vulnerable to stochastic events. In addition, USFWS (2009) identified climate change as a new threat. In consideration of the life history traits used by Anacker et al. (2013) for assessing climate change vulnerability in California, *C. robusta hartwegii* is highly vulnerable because of its low dispersal ability and habitat specialization.

Since listing in 1994, the landscape with the three occurrences of *C. robusta hartwegii* has become increasingly developed and fragmented, with development impacts resulting in the likely extirpation of 10 colonies (western occurrence, 4 colonies; central occurrence, 5 colonies; eastern occurrence, 1 colony). In 2014 the primary threats are habitat alteration due to adjacent land uses and developments, and invasive plant species and accumulation of thatch. Although *C. robusta hartwegii* is listed as endangered under the U.S. Endangered Species Act (USFWS 1994), this law provides little protection against the threats in 2014. Using our information and international standards (IUCN 2011, 2012), *C. robusta hartwegii* in 2014 meets the IUCN criteria for critically endangered: area of occupancy, 0.39 ha; extent of occurrence, 1.3 km²; landscape, severely fragmented; and quality of the habitat, continuing to decline. With these attributes, *C. robusta hartwegii* faces an extremely high risk of extinction. Therefore, as a matter of urgency, we

recommend reducing and controlling invasive plant species and thatch using a combination of methods: mowing with biomass removal, cutting by hand tools with biomass removal, pulling by hand with biomass removal, controlled grazing, prescribed mini-burns (testing 1 m²), and spot-treating invasive grasses with a grass-specific herbicide.

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